ASSESSMENT ON THE AVERAGE PARTICIPATION VERSUS BIALEK'S METHODS FOR TRANSMISSION PRICING METHODOLOGIES

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DEDICATION

"I dedicate this thesis to my beloved parents who give me moral support and motivation for me to complete this thesis. Next, dedicate to my Supervisor which is someone who always gives advice and helps me to solve the problems and guided me until finish my thesis. Besides that, thanks to my friends who always helped me and share their knowledge to complete this thesis. Lastly, without their support, it is very difficult for me to complete this thesis successfully. Thanks to all"

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ABSTRACT

Nowadays, the global trend especially in developing countries namely, Australia, New Zealand and Singapore and some countries are at various stages of developing a national electricity market has put pressure and force Malaysia to restructure electricity industry to be more reliable, effectively, transparent, efficient and sustainable. Currently, electricity supply industries do not provide an efficient services as competitive firms. Therefore, electrical industries in Malaysia need to move from a predominantly government owned and managed market to a more competitive and commercial one. One of the important issues in this restructuring market is the transmission pricing. The regulation of the transmission pricing is important in order to identify whether the transmission service system is economically beneficial to both side of users and utilities. In this research, 3 bus system and IEEE 6 bus system were used as case studies in order to determine the best method either the Average Participation or Bialek's methods that reflects fair and equitable transmission pricing methodologies. Using Average participation method, the each of the transmission line has the power contribution from each user which follows the nature of power injection. Meanwhile, by using Bialek's method the power contribution of each user to each line is not uniform since there are transmission lines that indicate no power injection from generators and loads. This will affect the allocation of charges for locational and non-locational components. Hence, from this research work, it can be concluded that the Average Participation method reflects an efficient transmission network as the charges is allocated based on the actual usage of the transmission user to the lines.

ABSTRAK

Pada masa kini, negara-negara membangun seperti Australia, New Zealand dan Singapura telah memberikan tekanan dan memaksa Malaysia untuk menyusun semula industri elektrik kepada yang lebih dipercayai, berkesan, telus, cekap dan mampan. Selain itu, industri bekalan elektrik pada masa kini tidak menyediakan perkhidmatan yang cekap sebagai firma yang berdaya saing. Oleh itu, industri elektrik di Malaysia perlu melakukan berubahan terutamanya dari sistem kerajaan dimiliki kepada pasaran yang lebih kompetitif dan komersil. Salah satu isu penting di pasaran penstrukturan semula ini adalah penghantaran harga. Peraturan penghantaran harga adalah penting untuk mengenalpasti sama ada sistem perkhidmatan penghantaran ekonomi memberi manfaat kepada kedua-dua sisi pengguna dan utiliti. Dalam kajian ini, 3 sistem bas dan IEEE 6 sistem bus telah digunakan sebagai kajian kes bagi menentukan cara terbaik sama ada kaedah ‘Average Participation’ atau ‘Bialek’s’ adalah kaedah terbaik bagi penghantaran yang adil dan saksama. Menggunakan kaedah ‘Average Participation’, setiap satu talian penghantaran mempunyai kuasa sumbangan dari setiap pengguna yang jenis suntikan kuasa. Sementara itu, dengan menggunakan kaedah ‘Bialek’s’ sumbangan kuasa setiap pengguna untuk setiap talian adalah tidak seragam kerana terdapat talian penghantaran yang menunjukkan tiada suntikan tenaga daripada janakuasa dan beban. Ini akan menjejaskan peruntukan caj bagi komponen locational dan non-locational. Oleh itu, dari kerja-kerja penyelidikan ini, maka dapatlah disimpulkan bahawa penyertaan kaedah ‘Average Participation’ mencerminkan satu rangkaian penghantaran yang cekap sebagai caj diperuntukkan berdasarkan penggunaan sebenar pengguna penghantaran untuk garisan.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS AND ABBREVIATIONS

C_{ij}	-	contribution by generator i to the load and external flow of common j
C_{ik}	-	contribution by generator i to the load and external flow of common k
F_{jk}	-	flow from common j to common k through the link
F_{ijk}	-	flow from common j to common k through the link coming from common i
I_k	-	internal flow of common k
P_{ij}		circuit flow (p.u)
X_{ij}		circuit reactance (p.u)
θ_{ij}		angle between the buses i and j (rad)
P_i		net injection
P_{Gi}		MW of generator at bus i
P_{Li}		MW of load at bus i
$[B]$		the bus susceptance matrix
Au		upstream distribution matrix
P		the vector of bus flows
P_G		the vector of bus generations
P_{Gk}		generation in node k
x		The prescribed transmission service
ORC		optimized replacement cost
ASRR		Annual Service Revenue Requirement
AARR		Aggregate Annual Revenue Requirement
TUoS		Transmission use of system
R_t		transmission price for transaction t

TC	total transmission charges
P_t	power of transaction
P_{peak}	system peak power
PX_t	MW-Mile Value
DT	Airline distance
PM	Power magnitude
L_k	length of line k in mile
C_k	cost per MW per unit length of line k
$MW_{t,k}$	flow in line k, due to transaction t
T	set of transactions
K	set of lines

CHAPTER 1

INTRODUCTION

1.1 Research Background

An electric power system is used to generate, transmit and distribute electrical energy in secure, reliable and economic ways. Normally, in electrical generation and transmission are used three-phase AC systems while distribution of electrical energy may use single-phase or two-phase systems [1]. Basically, there are three basic components in electricity power industry which is generation, transmission and distribution. Generation system which is used to generate the electrical energy from primal energy fuels. Next, transmission system is a network that normally used to transmit the electrical energy, over long distance from generation and delivers power to either distribution systems or load centers. While, distribution system is used to deliver the electrical energy to the end-use customers. Figure 1.1 shows the structure of electric power systems.

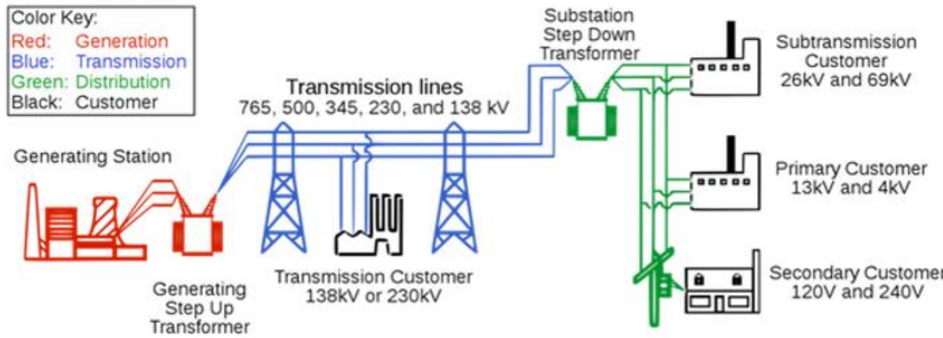

Figure 1.1: Structure of electric power systems [2]

In this research, the important issue is about transmission pricing by restructuring the electricity market. Transmission pricing is a service that recovers of existing and new cost of transmission system [3]. The regulation of the transmission pricing is important in determining whether the transmission service system is economically beneficial to both side of the users and utilities. When discussing on the transmission pricing, it is obviously reflect on the transmission service [3]. Each component of electric power has pricing services where the transmission pricing method is important in balancing the transaction from generator to the load. Beside that it can create system integrity with all tread equitable, fair and no discrimination for both sides because they have several issues arise particularly in transmission pricing due to restructuring process.

The definition of transmission pricing is transmission function will facilitate a competitive electricity market by impartially providing energy transportation services to all energy buyers and sellers, while fairly recovering the cost of providing those services [4]. In addition, the recovery cost is the cost which both side of generators and distribution (load) have to be charged a price as well as to allow correct decisions in terms of economic and engineering on upgrading and enhancing the generation, transmission and distribution facilities [5]. Therefore, there are several aspects need to focus for transmission pricing service in order to meet the requirements which are, the service must efficiency, offset the company fairly in delivering delivery services, allocate transmission cost reasonably among all transmission user and maintain the reliability of the transmission network [6].

Until the past decade, the electric power industry was widely viewed as a “natural monopoly”, meaning the cost of generating, transmitting, and distributing electricity would be lower if only one firm undertook each activity. The existence of a natural monopoly in any of these components provides some justification for granting an exclusive franchise, for example, limiting operation in that component to a single firm [7]. In order to make electricity systems more efficient, a competition is introduced by establishing a restructured environment where the utilities are required to unbundle their services into three components which are generation, transmission and distribution [8]. The restructuring of electricity market promotes the emergence of new technologies and minimize the electricity prices. The cost will be reduced by driving prices through market forces because of open access environment. Therefore, it will allow the consumer to choose which services are more efficient for electric energy. Moreover, the competitive environment will improve the supply quality and reliability of the transmission service [9].

In this research, the aim is to explore the Average Participation versus Bialek's methods for transmission pricing methodologies. There are three important steps to find the best transmission pricing charge. The first step is find the transmission usage evaluation (power flow DC) which is to know the amount used of power usage of generation and load to transmission networks. In this project, two methods of transmission usage evaluation will be investigated which are Average Participation and Bialek's method. Second step is the transmission charge allocation percentages of usage. This step is allocating the transmission service charge fairly among the transmission users. Last but not least, the step is transmission pricing method. The MW-Mile and Postage Stamp methods will be used in order to charge the transmission users which are the generators and loads.

1.2 Problem Statement

Nowadays, the global trend especially in developing countries namely, Australia, New Zealand and Singapore has put pressure and force Malaysia to restructure electricity industry to be more reliable, effectively, transparent, efficient and sustainable. Malaysia is one of country in stage of developing a national electricity market same as Brunei, China, Japan, Philippines, South Korea, Thailand and Vietnam. While, others countries like India, Indonesia, Cambodia, Laos and Myanmar are still trying to improve the level of electrification in their societies. Currently, electricity supply industries do not provide an efficient services as competitive firms. Malaysian electricity sector used to be controlled by a vertically integrated system. Reform in this sector has been implemented since the passing of the Electricity Supply Act 1990 and corporatization of the national electricity board in the same year [10]. Independent Power Producers (IPPs) entered the generation businesses in 1993. However deregulation has been interrupted due to power crisis in the 1990s. There is still monopoly in power purchase, transmission and distribution in the Malaysian electricity sector [11].

Therefore, electrical industry in Malaysia need move from a predominantly government owned and managed market (fully integrated or natural monopolies) to a more competitive and commercial. During these times, three main components in power energy which are generation, transmission and distribution systems are controlled by TNB. So in this case, these systems need to be changed by applying a new concept which is called deregulated market where the power utilities have been separated to Generation Company (GenCo), Transmission Company (TransCo) and Distribution Company (DistCo). The other reasons Malaysia need restructuring in electricity market to minimize the electricity prices (tariff). In addition, it is difficult to achieve the fairly transmission pricing to the users. Hence, the aim of this research is to identify the best method of the power contribution of users through the transmission lines and developing the transmission pricing methodology that is more fairly, reliable and efficient.

1.3 Objectives

There are three objectives that want to be achieved at the end of this research which are:-

1) To investigate the efficient transmission usage evaluation methods that determine the actual amount of power that contributes from each individual transmission user to each transmission line.
2) To determine the suitable charge allocation percentage of transmission users.
3) To develop a fair and efficient transmission pricing methodologies in order to charge the transmission users based on the actual usage of transmission networks.

1.4 Scopes

In order to fulfill the stated of objectives, the scopes of this research were focus on several aspects as follow:

1) DC power flow tracing was used to identify the net power flow of each transmission lines.
2) Power World Simulator was used to verify the DC power flow tracing result.
3) Bialek's and Average Participation Method (APM) were explored to determine the power contribution of each user to lines.
4) MW-mile and Postage Stamp methods were used for locational charges and non-locational charges, respectively.
5) Two cases studies were carried out which are 3 bus and IEEE 6 bus system to verify the effectiveness of the developed methodologies by using Matlab software.

1.5 Project Outlines

The structure of the thesis will summarize for every chapter as follows:

Chapter 1	Briefly explains on project background, the transmission pricing and three important steps. It also includes of the problem statement, objectives and scope of study.
Chapter 2	The literature reviews of the study were discussed in this chapter. This chapter also includes the concepts of restructuring elements and transmission sectors.
Chapter 3	Describes the methodology of the research through the flowchart. This part usually focuses on the method that has been chosen and a flowchart is shown in order to summarize the method for the purposed scheme.
Chapter 4	Discusses on the process in developing this research such as the method in calculating the transmission pricing and designs the appropriate system. There are two case studies that are used in order to provide an understanding on the concept of the proposed approach. The systems are tested in order to verify the result.
Chapter 5	The conclusion and recommendations of the study are discussed in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter is about the understanding of the research and the previous work. All of these fundamental, theories, knowledge and analysis information are based on previous studies that have been made with reference to the various books, articles, journals and internet.

2.2 Restructured Electricity Market

The main purpose of restructuring is to let economic forces drive the price of electric supply and maximize social welfare via competition [1]. Restructuring creates an open environment by allowing electric supply to compete and customers to choose the supplier of electric energy. Normally, restructuring requires the decomposition of three component of electrical industry namely generation, transmission and distribution. The separation of transmission ownership from transmission control is needed to ensure fair and nondiscriminatory access to the transmission services and ancillary services. The market structure is including the Independent System Operator (ISO), Generator companies (GENCOs), transmission companies (TRANSCOs), distribution companies (DISCOs) and retailers (RETAILSCOs) are collectively known as the Market Participants (MPs) [12]. Figure 2.1 illustrated a competitive electricity market structure with energy flow and information flow among its entities.

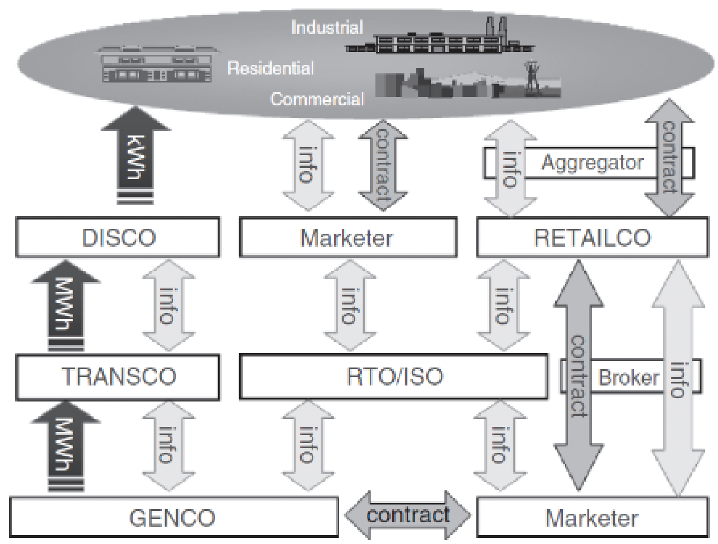

Figure 2.1: A competitive electricity market structure [13]

2.2.1 Independent System Operator (ISO)

Independent System Operator (ISO) established to control the grid system network. The ISO have the responsibility of ensuring the reliability of the one or more than one control areas [1]. ISO should be works in a fair and non-discrimination. Actually, the ISO is neutral, independent entity responsible for maintaining secure and economic operation of an open access transmission system on a regional basis. It also responsible for maintaining the energy balance of the system by controlling the dispatch of flexible resources. In addition, ISO provides transmission availability and pricing services to all user of the transmission grid. The main task for the ISO is the management of transmission congestion including the collection and distribution of congestion revenue. ISO is very important during the restructuring power system market to ensure the independent companies charges more to the customers and make it feels burdens to the users. ISO will regulate the price of electricity bids by the users and the suppliers.

2.2.2 GENCOs

Generator companies (GENCOs) is an entity that operates and maintains existing generation plants. In the restructured power market, the objective of GENCO is to maximize the profit. GENCO have the opportunity to sell electricity to customers which the price is negotiable through sales contracts. Besides, GENCOs may also trade reactive power and other ancillary services [1]. Open transmission access allows GENCOs to access the transmission network without distinction and to compete [3]. GENCOs are responsible to communicate generating unit outages for maintenance to ISO.

2.2.3 TRANSCOs

Transmission companies (TRANSCO) is an entity responsible for building, owning, and operating transmission systems in a geographical region for maintaining the overall reliability of the electrical system and TRANSCO also the most important elements in electricity markets. The efficiency of the transmission operation system is the key to the efficiency in these markets. The use of TRANSCO assets is under the control of the regional ISO. A TRANSCO transmits electricity using a high-voltage bulk transport system from GENCOs to DISCOs who delivers electricity to customers. Normally, the losses of power happened during the transfer of power through the transmission line. The TRANCOs should provide the efficient of the transmission service so that the losses could be reduce. TRANCOs are function as the company that give the service to the

GENCOs, DISCOs and users for transferring the power. So, TRANSCOs shall ensure that service provided are not detrimental any parties.

2.2.4 DISCOs

A DISCO is the last elements in the grid power systems and an entity that receives bulk energy from the transmission grid and distributes the electricity through its facilities to customers in a certain geographical region [1]. It is responsible for building and operation in electric system to maintain the reliability and availability to end user customers. DISCOs are responsible for responding to distribution network outages and power quality concerns. DISCOs are also responsible for maintain the distribution voltage support as well as ancillary services [13].

2.2.5 RETAILCOs

A RETAILCO is newly created entity that has legal approval to sell retail electricity [1]. A retailer may likely bundle electricity products and services in various package for sale. Aggregators are used by retailer to deal indirectly with customers.

2.3 Market Models in Restructuring Power System

In practice worldwide, the three models are being applied in the restructured power system. The three models are:

- PoolCo Model
- Bilateral Contracts Model
- Hybrid Model

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APPENDIX A